SAR Wind Maps and Derived Products: New Possibilities for Offshore Wind Energy Exploitation

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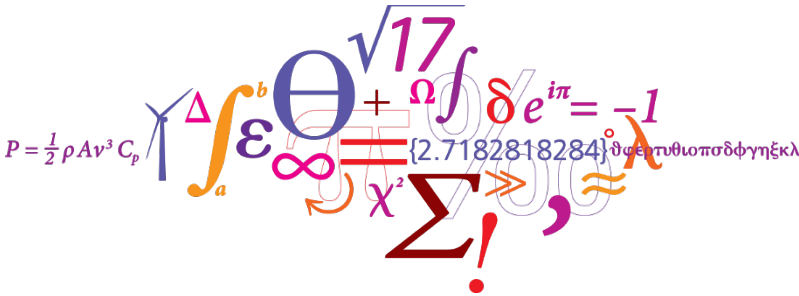
SAR Wind Maps and Derived Products:

New Possibilities for Offshore Wind Energy Exploitation

Merete Badger, Tobias Ahsbahs,
Ioanna Karagali, **Charlotte Hasager**



DTU Wind Energy
Department of Wind Energy

CEASELESS

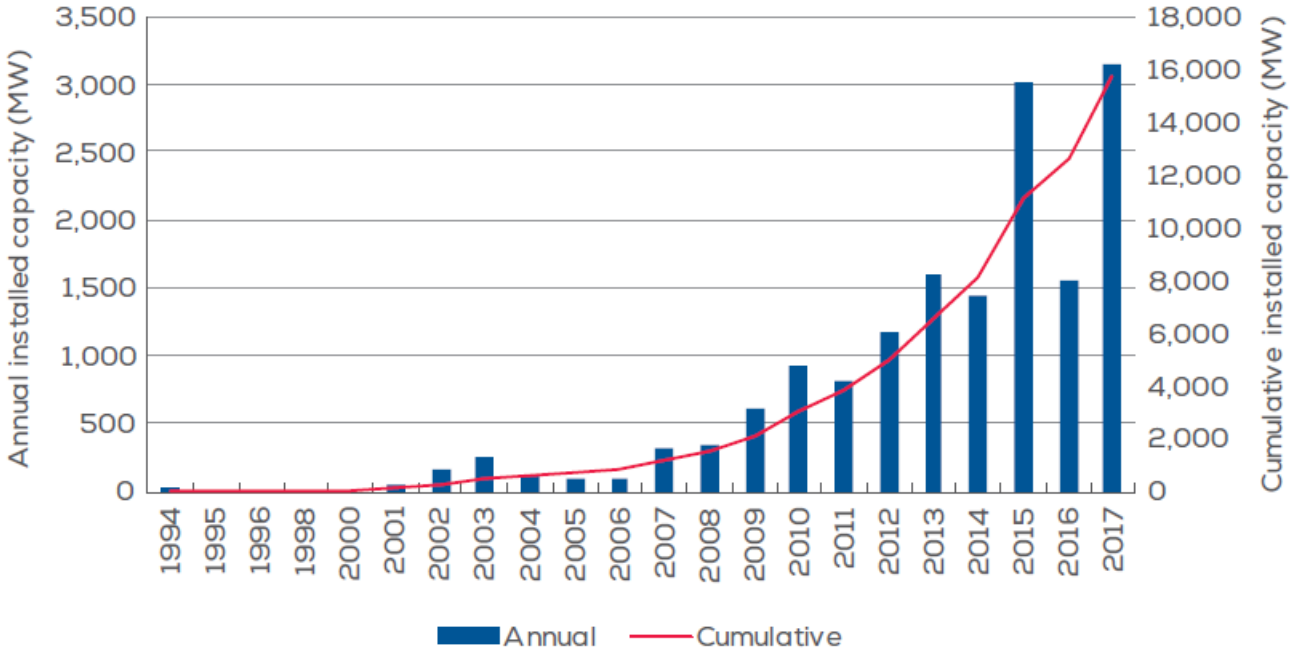
Wind energy production

EU: Wind energy cover 11.6% of the EU's electricity demand.

Denmark: Wind energy cover 44% of Denmark's electricity demand.

Offshore wind energy capacity in Europe

Cumulative and annual offshore wind installations (MW)

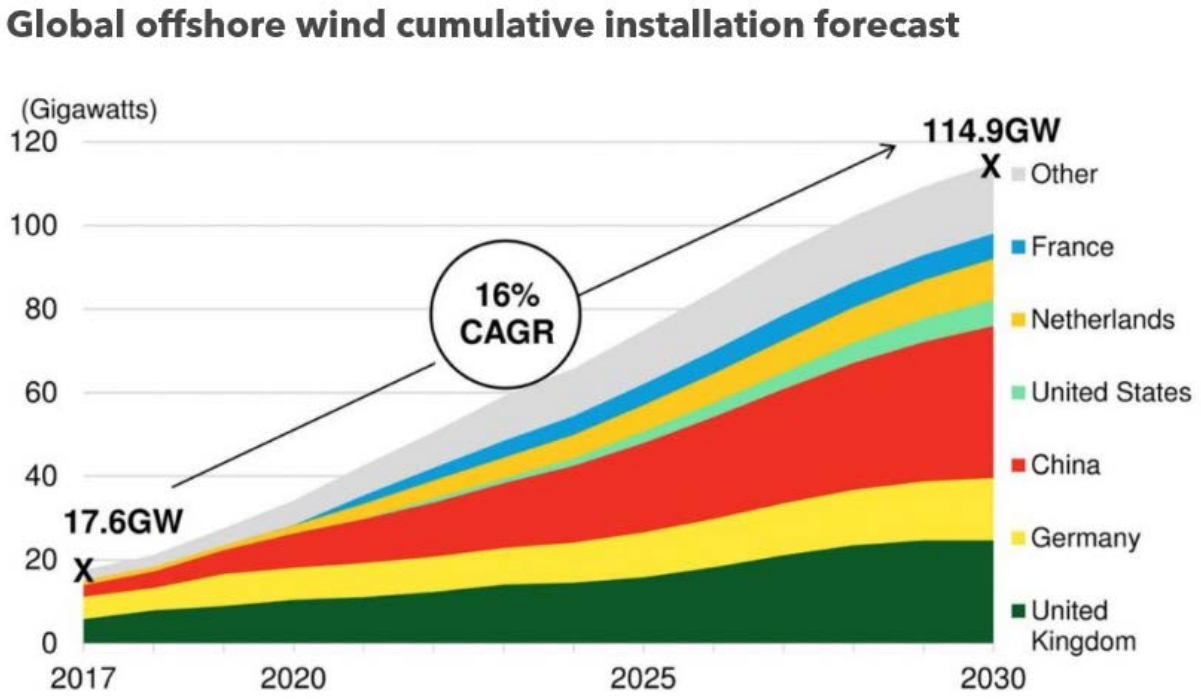


Source: WindEurope

4,149 offshore turbines.

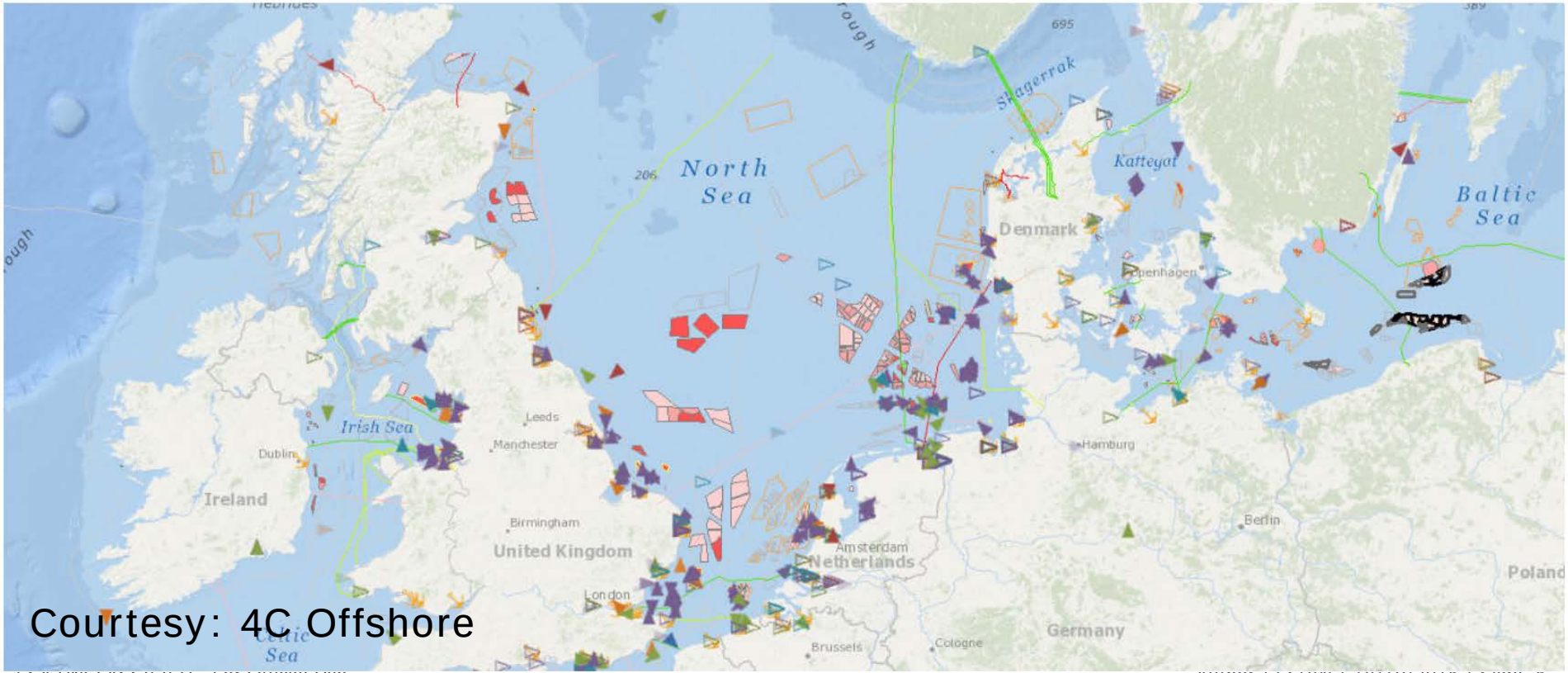
Two 350 MW wind farms, to be built by 2022 offshore in the Netherlands, will be the world's first to be built without public subsidy.

Global forecast



Source: BNEF

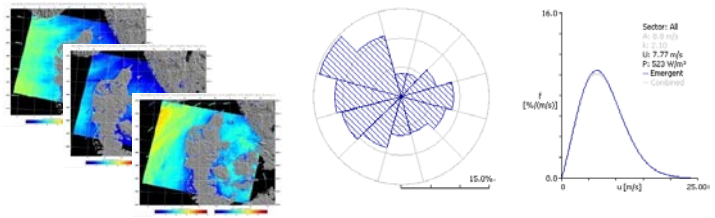
Map of offshore wind farms



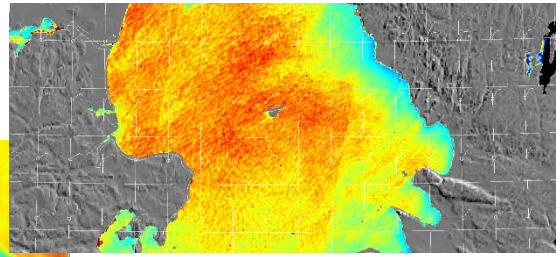
Courtesy: 4C Offshore

Offshore wind energy and SAR

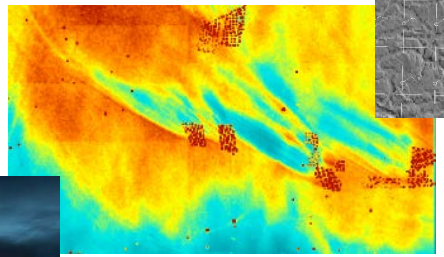
- Mean wind conditions



- Horizontal coastal wind speed gradients



- Wind farm wake effects



Courtesy: Patrick Volker, OffshoreWake project

- Extreme events

Courtesy: Hybrid Wind

SAR wind data archive at DTU

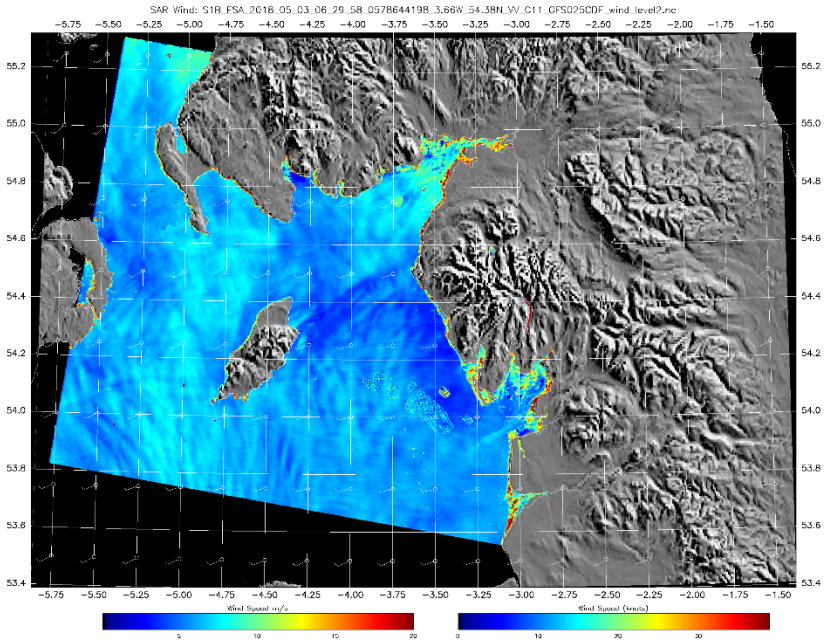
Image courtesy: Google Earth

View, search and download wind maps:

https://satwinds.windenergy.dtu.dk/

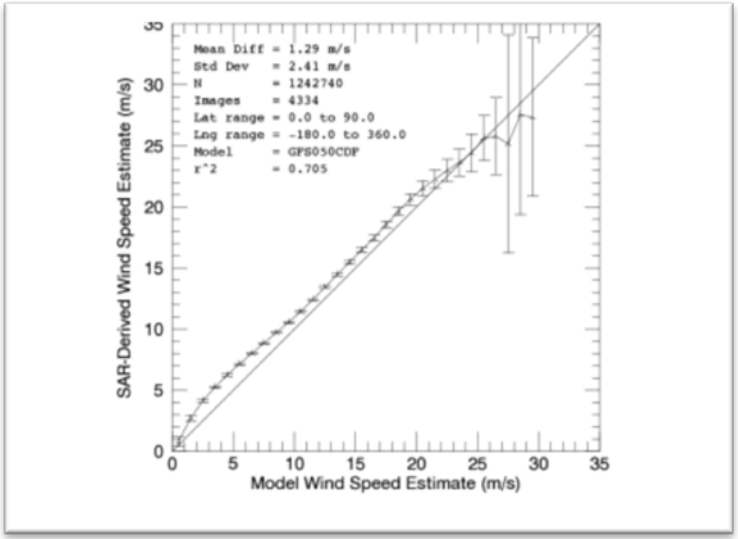
SAR wind data archive at DTU

- 30,000+ ENVISAT ASAR scenes
- 100,000+ Sentinel-1 A/B SAR scenes
- Wind processing using SAROPS tool by APL/NOAA
- Processing choices:
  - GMF: CMOD5.n
  - Pol. ratio for HH: Mouche et al. (2005)
  - Wind direction input: GFS model

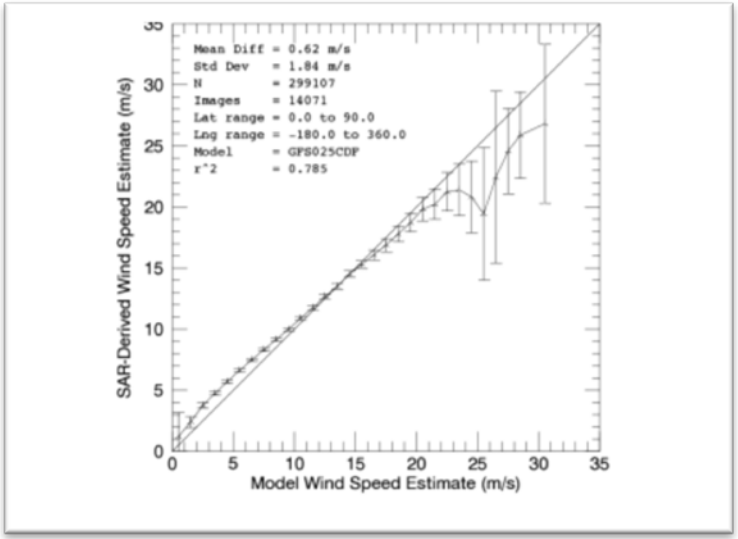


Wind map from Sentinel-1B, Irish Sea, May 3 2018 at 06:29 UTC

Wind speed comparisons - model



Envisat ASAR vs. GFS model

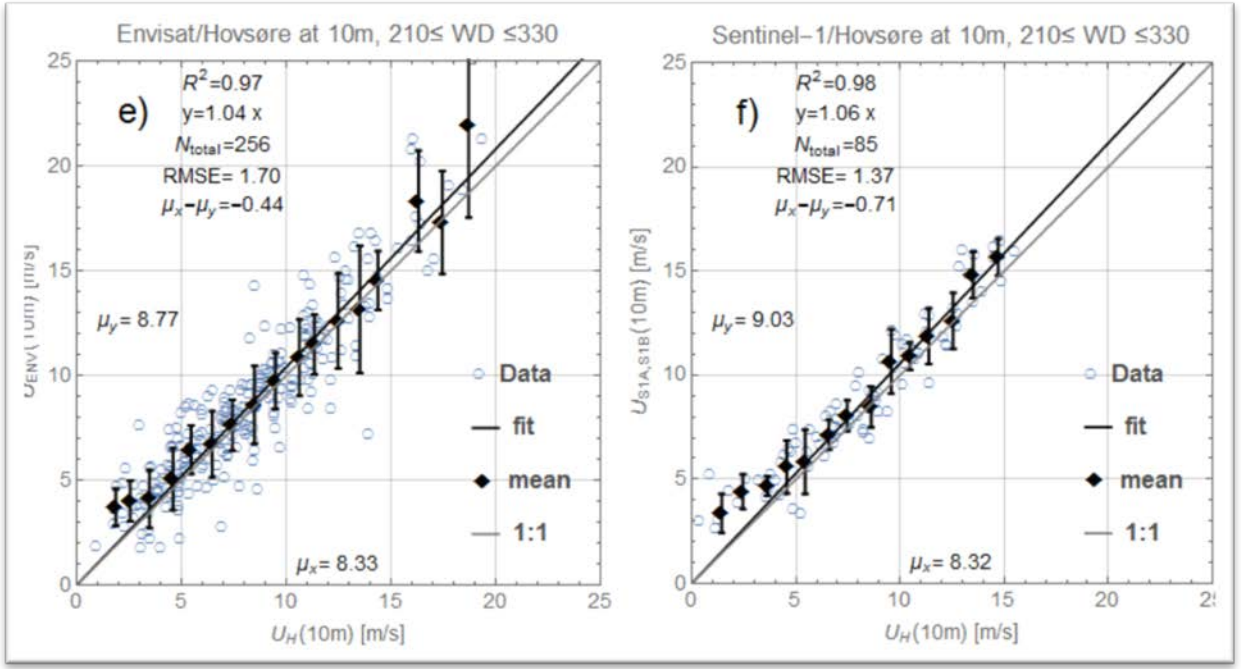


Sentinel-1A SAR vs. GFS model

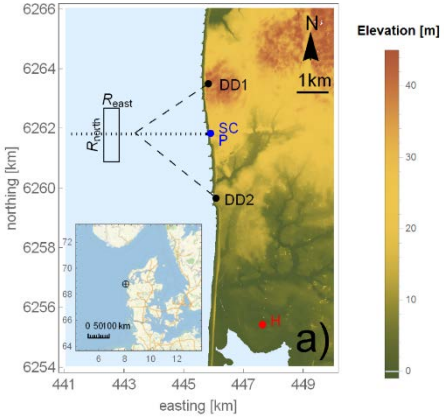
See also: Monaldo, F.M *et al*. (2015): Preliminary evaluation of Sentinel-1A wind speed retrievals. IEEE JSTARS, doi: 10.1109/JSTARS.2015.2504324.

Wind speed comparisons – mast

Høvsøre, Denmark



Wind speed comparisons – lidar



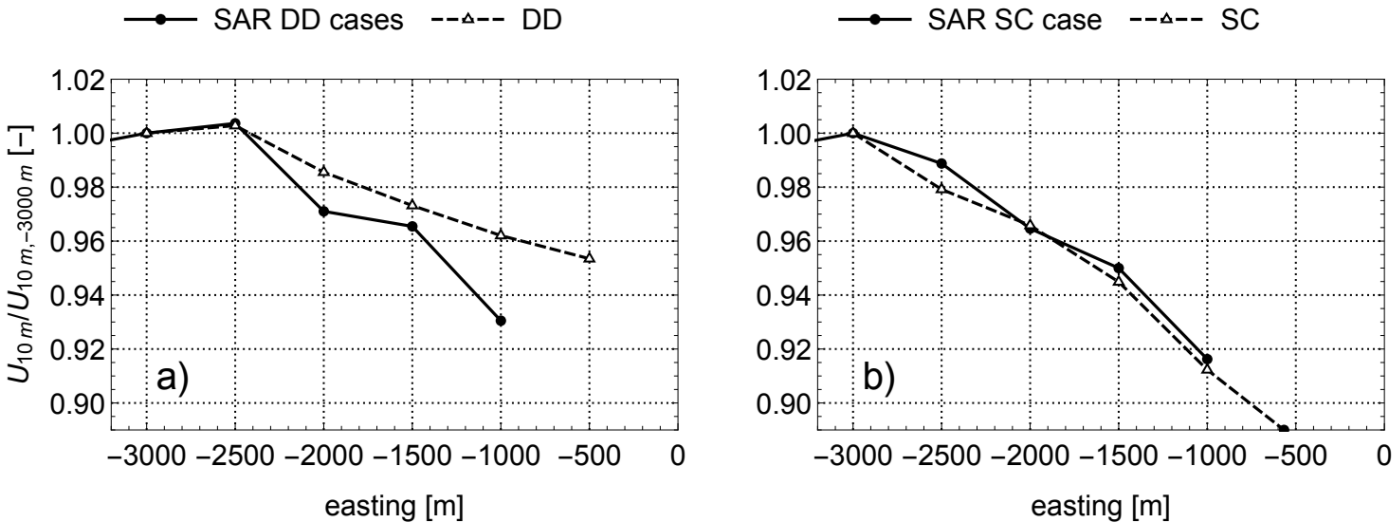
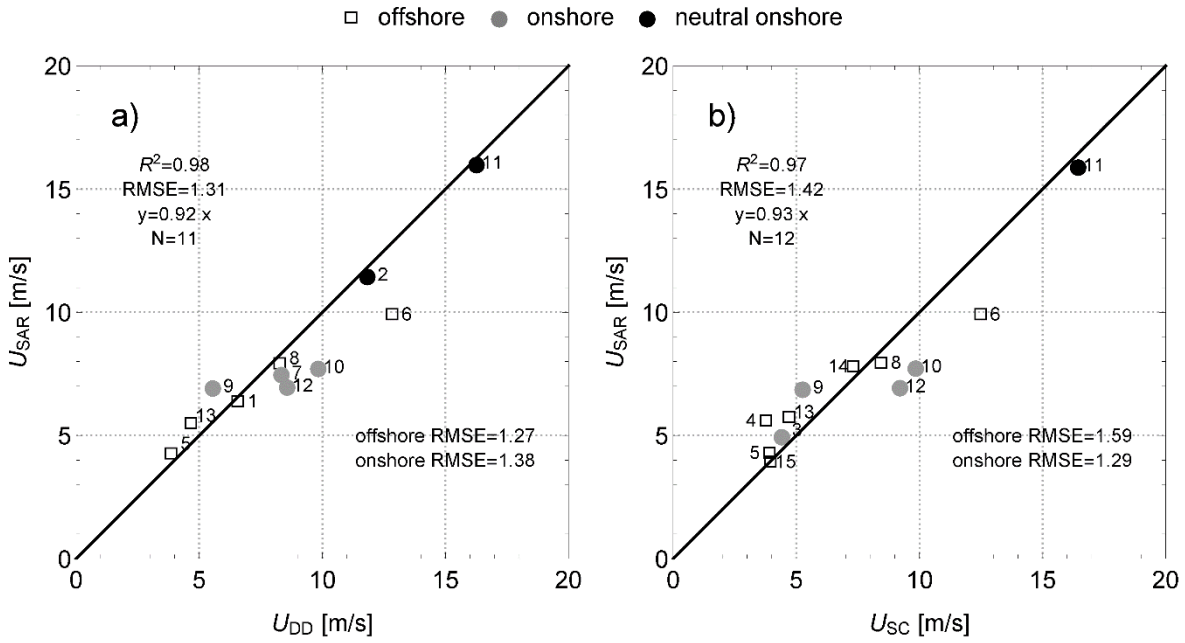


Figure 6. Relative wind speed nodimensionalized with the wind speed at −3000 m for from the LiDAR and the SAR for (**a**) the dual Doppler and (**b**) the sector scans.

From: Ahsbahs, T.; Badger, M.; Karagali, I.; Larsén, X.G. Validation of Sentinel-1A SAR Coastal Wind Speeds Against Scanning LiDAR. *Remote Sens.* **2017**, *9*, 552, doi:10.3390/rs9060552

Wind speed comparisons – lidar



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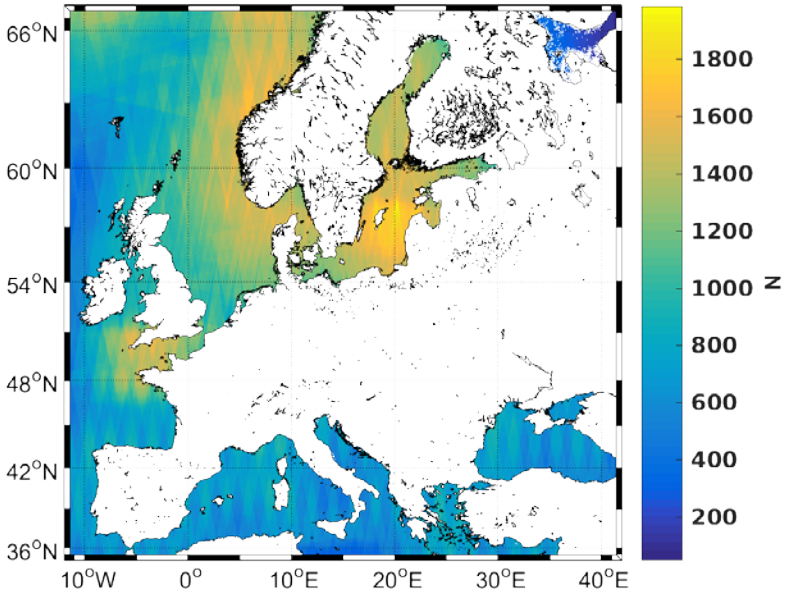
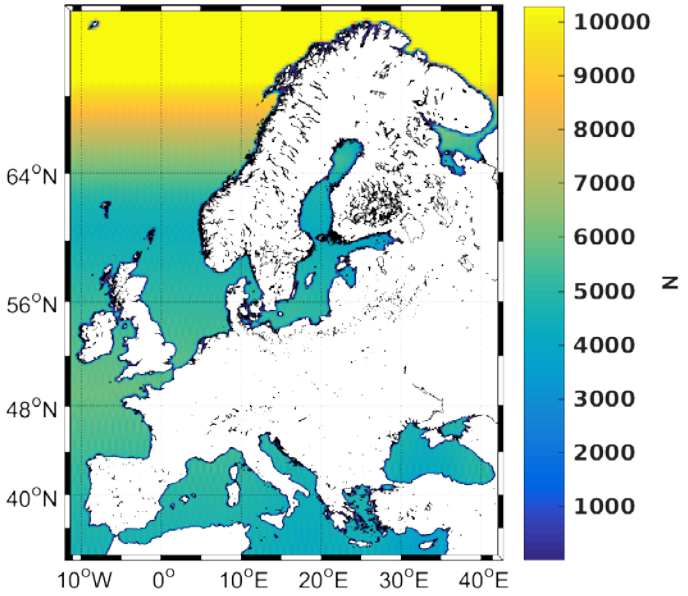
10-m offshore wind atlas for Europe

Number of samples



Envisat and Sentinel-1 A/B

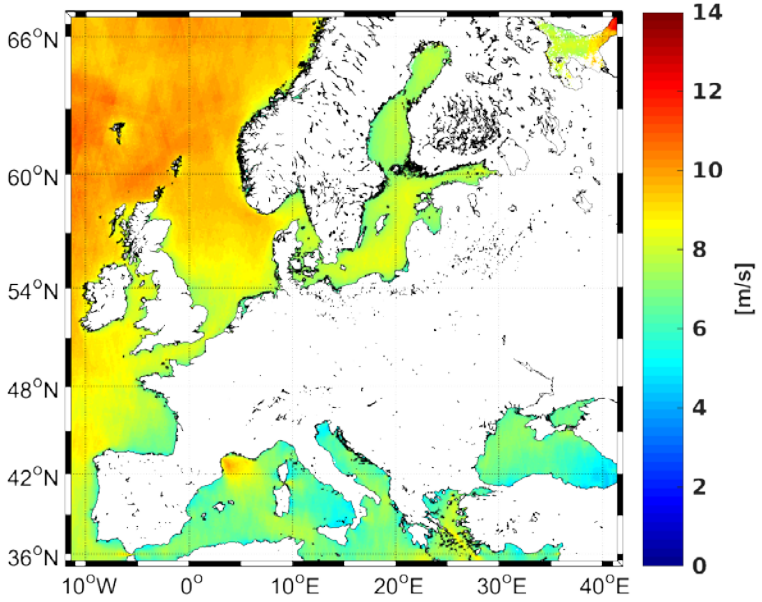


ASCAT

From: Karagali et al. New European wind atlas offshore, Journal of Physics: Conference Series (accepted).

10-m offshore wind atlas for Europe

Mean wind speed



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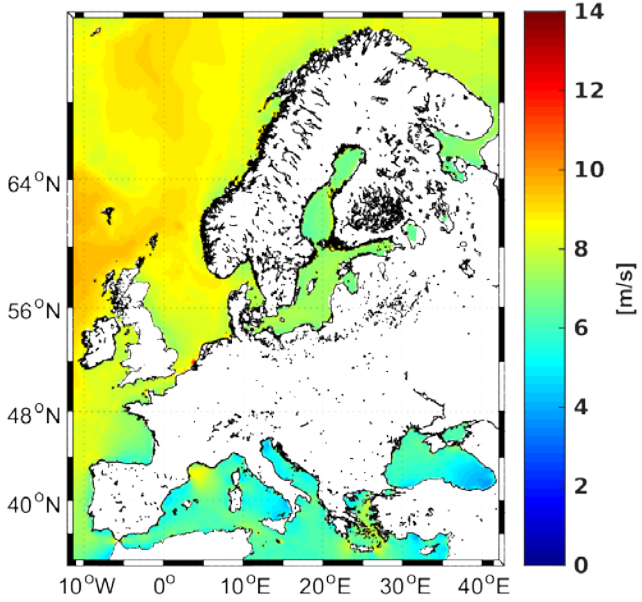


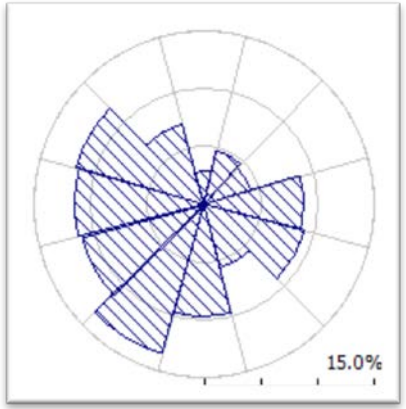
ASCAT

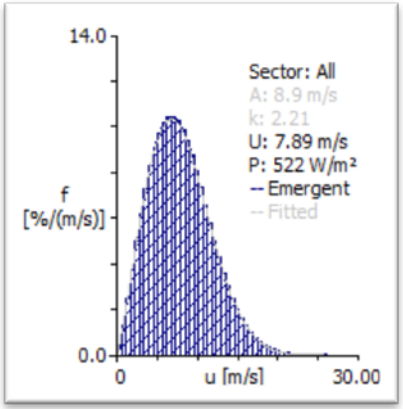
From: Karagali et al. New European wind atlas offshore, Journal of Physics: Conference Series (accepted).

Wind atlas statistics

Each grid cell:

- 0.02° latitude/longitude
- Weibull scale and shape parameters
- Wind power density



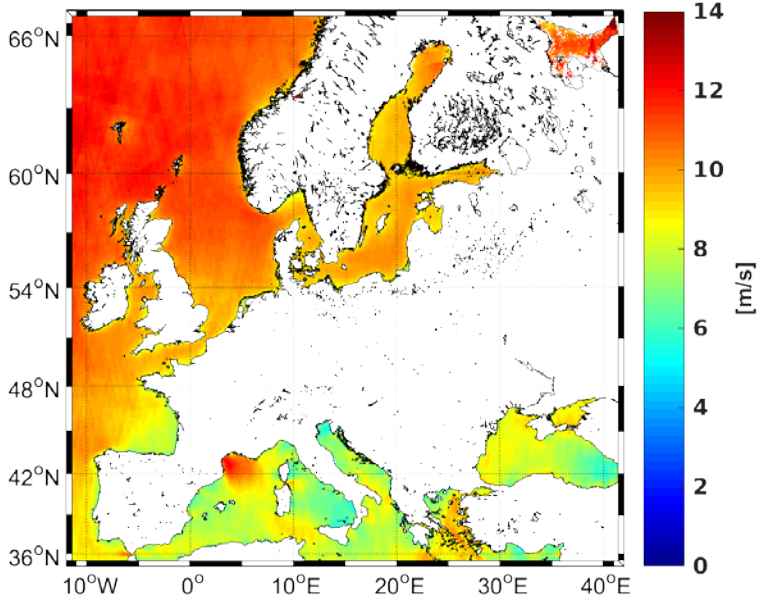


	Weibull-A	Weibull-k	Mean speed	Power density
Fitted	8.9 m/s	2.21	7.88 m/s	522 W/m²
Emergent	-	-	7.89 m/s	522 W/m²
Combined	8.9 m/s	2.22	7.89 m/s	522 W/m²

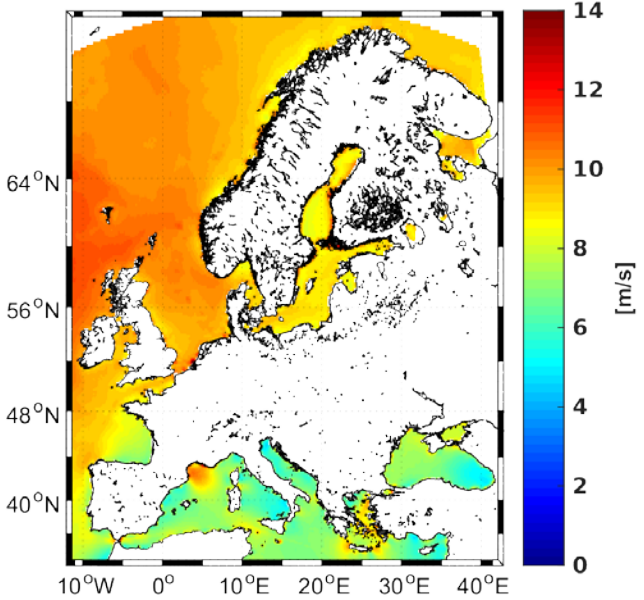
Example site in the North Sea

100-m offshore wind atlas for Europe

Mean wind speed



Envisat and Sentinel-1 A/B



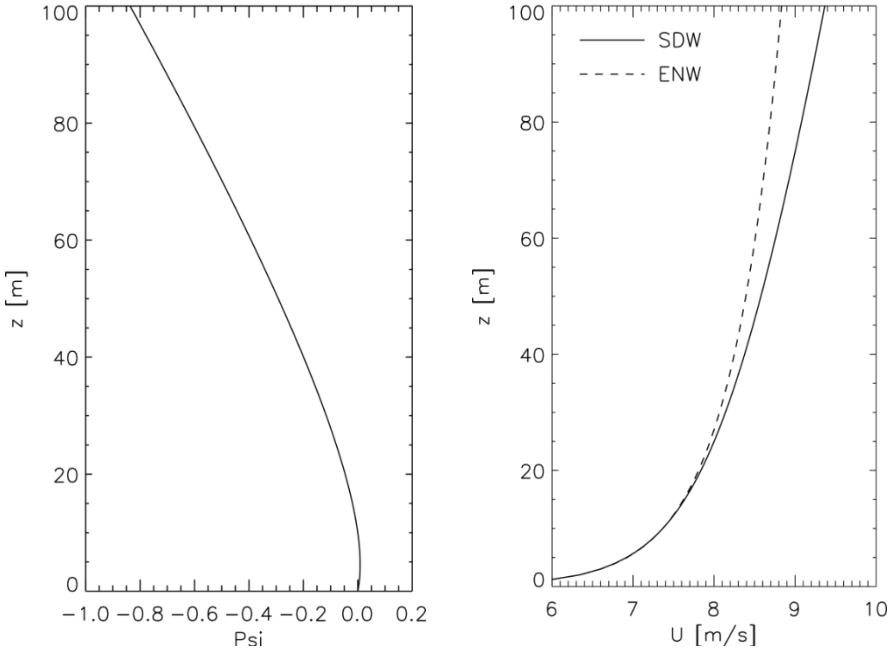
ASCAT

From: Karagali et al. New European wind atlas offshore, Journal of Physics: Conference Series (accepted).

Extrapolation of SAR wind speeds to hub height

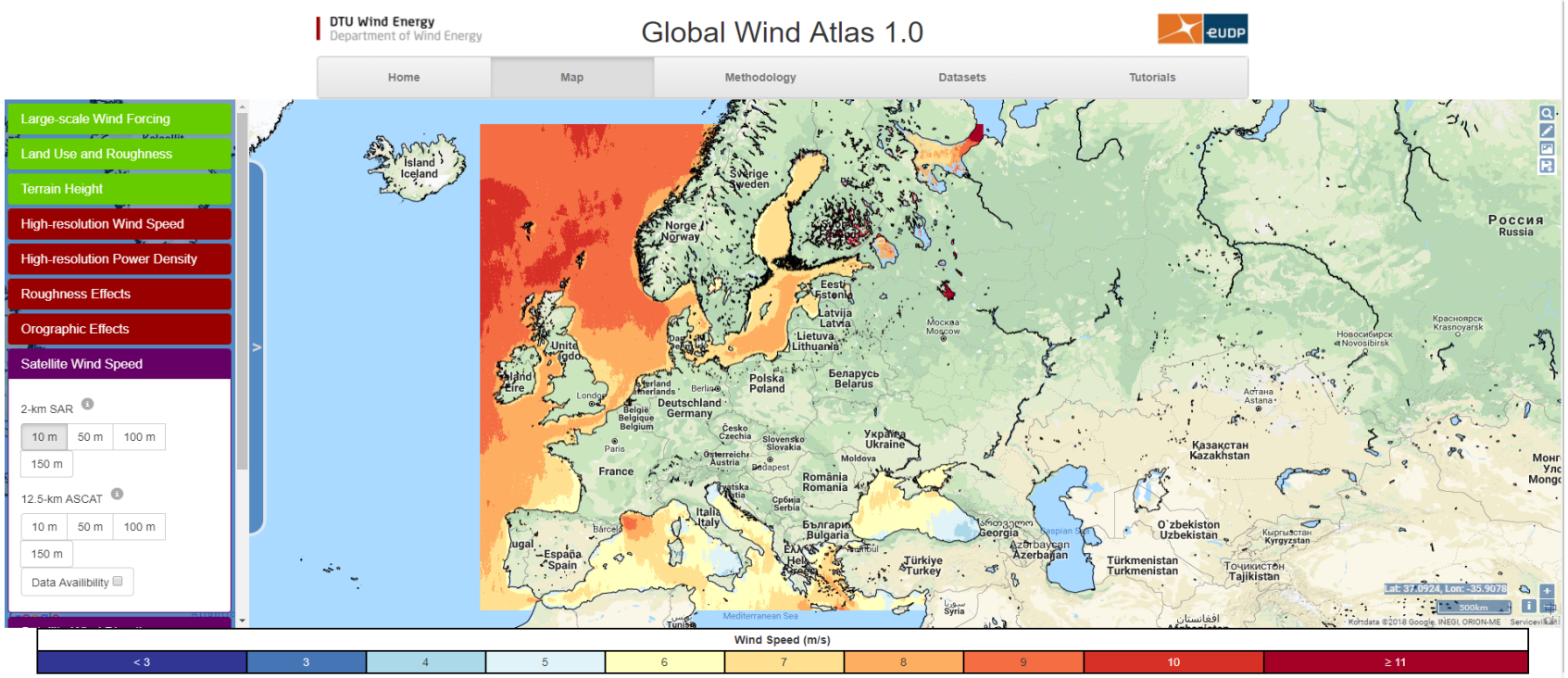
- Based on the numerical weather prediction model WRF
- Long-term average stability correction and wind profile
- Differences between SDW and ENW can be large

$$\left\langle \frac{\kappa\, u(z)}{u_*} \right\rangle = \ln\left(\frac{z}{z_0}\right) - \langle \psi_m \rangle$$



Badger, M. et al.(2016): Extrapolating satellite winds to turbine operating heights, *Journal of Applied Meteorology and Climatology*, 44, 975-991, doi: 10.1175/JAMC-D-15-0197.1.

Global Wind Atlas



http://science.globalwindatlas.info/science.html

Conclusions

- Open access to SAR observations and derived products has eased application in the wind energy community
- SAR wind samples have reached numbers that are satisfactory for wind energy resource assessment – and new data is collected daily
- Methods for wind extrapolation from 10 m to the turbine hub height exist
- Remaining challenges:
  - Calibration consistency is crucial for wind ressource estimation (Envisat vs. S-1 A/B)
  - Incidence angle dependence persists (positive wind speed bias at high incidence angles)
  - GMFs may be optimized and input wind direction inputs improved
  - Reprocessing of large image archives is computationally challenging

Acknowledgements

- Satellite SAR data from the European Space Agency and Copernicus.
- The SAR Ocean Products System (SAROPS) by the Johns Hopkins University, Applied Physics Laboratory and the US National Atmospheric and Oceanographic Administration (NOAA).
- In situ observations from NOAA's National Data Buoy Center and DTU's test station Høvsøre.
- This work received funding from the EU H2020 program under grant agreement no. 730030 (CEASELESS project), ERANET+ (NEWA project), and the Danish National Funding programme ForskEL (RUNE project).

Thank you